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A SUMMARY OF THE 1988 EPA NATIONAL PERFORMANCE AUDIT PROGRAM ON SOURCE MEASUREMENTS

by

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16. ABSTRACT

In 1988, the Quality Assurance Division conducted the National Audits for Stationary Source Test Methods. The audit materials consisted of: a disposable gas cylinder for Method 3 (Orsat analyzer), a calibrated orifice for Method 5 (DGM only), five simulated liquid samples each for Method 6 (SO_2) and Method 7 (NO_x), and two coal samples for Method 19. Participating laboratories sent their data to the Source Branch and in return received a written report comparing their results to EPA's.

In the Method 3 audit, each parameter had only one concentration. The mean for CO_2 was 4.2% from the expected (EPA) value. The mean for O_2 was 0.4%.

In the Method 5 audit, the mean value for all participants differed by 3.1% from the expected value. For the Method 6 audit, the average mean differed by 3.9% from the expected value, and in the Method 7 audit, the average mean differed by 23.7%.

In the two coal audits, the parameters measured were sulfur, moisture, ash, and Btu content. On the average, for the sulfur analysis, 91% of the participants measured within 10% of the expected value; for Btu, 97% of the participants measured within 10% of the expected value.

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the environment, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection regulations through the monitoring of long-term trends. The Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina, has responsibility for: assessment of environmental monitoring technology and systems; implementation of Agency-wide quality assurance programs for air pollution measurement systems; and supplying technical support to other groups in the Environmental Protection Agency, including the Office of Air and Radiation and the Office of Toxic Substances.

The major task of this study was to report the results of the national quality assurance audit program for stationary source test methods. Audits were designed to estimate the minimal analytical and computational accuracy that can be expected with Method 3 (carbon dioxide and oxygen), Method 5 (dry gas meter only), Method 6 (sulfur dioxide), Method 7 (nitrogen oxides), and Method 19 (coal). Statistical analysis was used to characterize the data.

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ABSTRACT

In 1988, the Quality Assurance Division conducted the National Audits for Stationary Source Test Methods. The audit materials consisted of: a disposable gas cylinder for Method 3 (Orsat analyzer), a calibrated orifice for Method 5 (dry gas meter only), three simulated liquid samples for Method 6 (SO_2) and Method 7 (NO_x), and two coal samples for Method 19. Participating laboratories sent their data to the Research and Monitoring Evaluation Branch and in return received a written report comparing their results to EPA's.

In the Method 3 audit, each gas component had only one concentration. The mean CO_2, O_2, and CO values for all participants differed by 4.2 percent, 0.4 percent, and 16 percent from the expected value, respectively.

In the Method 5 audit, the mean value for all participants differed by 3.08 percent from the expected value. In the Methods 6 and 7 audits, the average means differed by 3.9 percent and 23.7 percent from the expected values, respectively.

In the two coal audits, the parameters measured were sulfur, moisture, ash, and Btu content. On the average, 91 percent of the participants measured sulfur within 10 percent of the expected value and 97 percent of the participants measured Btu content within 10 percent of the expected value. The corresponding results for ash and moisture were 98 percent and 57 percent, respectively.

This report includes the results of the performance audits done during the period from January to December 1988.

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We express our appreciation to the laboratories that participated in the National Performance Audit Program for Stationary Sources. Thanks also to the staff of the Standards Laboratory/Research and Monitoring Evaluation Branch/Atmospheric Research and Exposure Assessment Laboratory (AREAL), who did the acceptance testing of the audit samples, and to the programmers of the Exposure Assessment Research Division/AREAL for providing the data systems to store and evaluate the data.

SECTION 1

INTRODUCTION

The Environmental Protection Agency's (EPA's) Atmospheric Research and Exposure Assessment Laboratory (AREAL) at Research Triangle Park, North Carolina, established an audit program in 1977 to evaluate the performance of companies that conduct compliance testing using EPA test methods. The audits check the participants' analytical accuracy in applying the analytical phase of EPA Test Methods 3, 6, 7, and 19 and the calibration accuracy of the Method 5 control console.[1] Accuracy is defined as the percent difference between a participant's analytical results and the EPA expected value. By participating in this free and voluntary program, testing companies can compare their performance to the performance of other laboratories conducting similar measurements.

Source Test Methods 3, 5, 6, and 7 were each audited once, and Method 19 was audited twice in 1988. Each participating laboratory received an audit package consisting of the audit sample, a data sheet, instructions, and an envelope for returning the data to EPA. Participants had 8 weeks to use the audit material and return their data to EPA. At the end of this period, all data received were statistically analyzed to determine the accuracy achieved with respect to the expected value and to provide the participants a means to compare their performance to that of all the laboratories that participated in the audit. This latter comparison can be done using the histograms in Appendix A.

This report summarizes the results obtained in the 1988 audits for stationary sources.

SECTION 2

SUMMARY

In 1988, EPA's AREAL at Research Triangle Park, North Carolina, conducted National Quality Assurance Audits for Stationary Source Test Methods 3 (Orsat analyzer), 5 (dry gas meter only), 6 (SO_2), 7 (NO_x), and 19 (coal). Industrial laboratories, contractors, foreign laboratories, as well as local, state, and federal agencies, participated.

The results of the 1988 audit of Method 3 are summarized in Table 1. Participants analyzed the gas sample twice for percentages of carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO). The mean values of CO_2 and O_2 differed by 4.2 percent and 0.4 percent from the expected values, respectively. The mean value for CO differed by 16 percent from the expected values.

TABLE 1. PARTICIPANTS' RESULTS FROM METHOD 3 AUDIT
(ALL DATA--NO OUTLIERS REMOVED)

Type of sample	Parameter	No. of analyses	Replicate	EPA true value	Participant results		
					Mean	Median	Std. dev.
Small cylinder (gas)	% CO_2	55	1	8.10	7.77	7.70	0.86
		54	2	8.10	7.76	7.70	0.88
	% O_2	55	1	8.90	8.93	9.00	0.33
		54	2	8.90	8.95	8.95	0.36
	% CO	34	1	0.80	0.66	0.65	0.24
		33	2	0.80	0.68	0.70	0.24

The mean for all participants in the Method 5 flow audit was 3.08 percent from the expected value, and the standard deviation was 3.85 percent. After the removal of 9 percent of the data to eliminate statistical outliers, the mean was 1.57 percent from the expected value and the standard deviation was 0.99 percent. The participants' performance based on the standard deviation of all data was good and was consistent with previous years.[2,3,4,5]

Tables 2 and 3 present the data (no outliers removed) from the Methods 6 and 7 audits, respectively. In the Method 6 audit, the procedure requires the participants to determine the sulfate content in three aqueous solutions using the titration procedure. For all three concentrations, the mean of the combined participants' results was less than 5 percent from the expected value, and the median differed by less than 2 percent.

The Method 7 audit procedure requires that the participants determine the nitrate content in three aqueous solutions. For all three concentrations, the mean was greater than 10 percent from the expected value, but the median was less than 1 percent.

TABLE 2. PARTICIPANTS' RESULTS FROM METHOD 6 AUDIT
(ALL DATA--NO OUTLIERS REMOVED)

No. of analyses	EPA true value (mg/DSCM)	Participant results		
		Mean	Median	Std. dev.
75	305.0	321.9	307.9	146.3
75	610.0	616.4	590.4	287.6
75	1296.0	1339.5	1287.0	625.7

TABLE 3. PARTICIPANTS' RESULTS FROM METHOD 7 AUDIT
(ALL DATA--NO OUTLIERS REMOVED)

No. of analyses	EPA true value (mg/DSCM)	Participant results		
		Mean	Median	Std. dev.
60	125.0	162.7	126.0	182.3
59	284.0	346.1	286.0	334.3
60	637.0	759.2	633.1	863.9

Table 4 summarizes the results from the two coal audits that were conducted in 1988. Participants analyzed each coal sample in duplicate for percentages of sulfur, moisture, ash, and gross calorific value (Btu/lb). The means of the ash and sulfur results were within 4 percent of the expected value, and the mean for moisture was within 8 percent. The mean of the Btu results was within 1 percent of the expected value. The Btu content as measured by the participants is likely slightly lower than the EPA value because coal oxidation is not prevented in the audit sample. The Btu content results are a good example of the accuracy with which a measurement can be made when that measurement receives good laboratory quality control.

TABLE 4. PARTICIPANTS' RESULTS FROM METHOD 19 COAL AUDITS
(ALL DATA—NO OUTLIERS REMOVED)

Audit date	Parameter	No. of analyses	EPA value	Participant results		
				Mean	Median	Std. dev.
0388	% S	125	0.77	0.78	0.77	0.18
0988		112	4.08	3.96	3.98	0.27
0388		125	2.05	2.04	2.04	0.10
0988		114	4.59	4.47	4.49	0.33
0388	% H_2O	125	0.94	0.93	0.91	0.27
0988		113	1.99	1.82	1.86	0.27
0388		125	3.54	3.39	3.45	0.38
0988		115	7.59	7.47	7.51	0.51
0388	% Ash	125	7.92	7.95	7.89	1.04
0988		115	14.75	14.22	14.22	0.39
0388		125	13.28	13.27	13.29	0.24
0988		113	17.84	17.63	17.59	0.36
0388	Btu/lb	121	13309.00	13309.45	13305.00	96.52
0988		109	11761.00	11745.78	11797.00	242.35
0388		121	13333.00	13298.71	13309.00	171.28
0988		107	11823.00	11847.13	11873.00	213.10

SECTION 3

METHOD 3 AUDIT

The Method 3 audit checks the participants' abilities to analyze a gas sample using an Orsat analyzer. The audit package consists of a disposable cylinder that contains a 4-liter (L) sample of CO_2, O_2, and CO. The analyst expels the gas into the Orsat analyzer using the positive pressure of the cylinder. The gas sample is quantitatively analyzed for percentage of CO_2, O_2, and CO.

In the 1988 audit, 57 percent of the 92 laboratories receiving the audit package returned data. Table 5 shows the total number of laboratories requesting participation and the number that returned data for the Method 3 audit.

TABLE 5. METHOD 3 AUDIT PARTICIPANTS

Category	No. receiving samples	No. returning data
Contractors	44	23
Industry	32	19
Foreign	2	1
Federal	2	2
State	9	5
Local	3	2
Total	92	52

Table 6 summarizes the Method 3 audit results in terms of the percentage of the results within 5 and 10 percent of the expected value. Each laboratory was asked to analyze the sample in duplicate. Fifty-three percent of the reporting laboratories achieved an accuracy within 5 percent for CO_2, and 85 percent achieved an accuracy within 5 percent for O_2. For the CO analysis, only 32 percent of the laboratories achieved an accuracy within 5 percent; 38 percent of the laboratories did not report a value for CO.

TABLE 6. SOURCE METHOD 3 AUDIT

Parameter	Expected value	No. of analyses*	Laboratories accurate within 5% (%)	Laboratories accurate within 10% (%)
CO_2	8.10	(1) 55	53	84
		(2) 54	48	83
O_2	8.90	(1) 55	85	95
		(2) 54	81	93
CO	0.80	(1) 34	32	32
		(2) 33	27	27

*Numbers in parentheses indicate first and second analyses.

SECTION 4

METHOD 5 DRY GAS METER AUDIT

In the Method 5 audit procedure, participants use a calibrated orifice to check the calibration of the dry gas meter in their EPA Method 5 control console (meter box). They insert the orifice in the Method 5 meter box, allow the box to warm up, and then make three 15-min volume measurements. The participants convert each of the three volumes to cubic meters at standard conditions using the formula specified in Eq. 5.1 of Method 5 (Appendix A, 40 CFR 60) and record them on the data card. Then they return the orifice and the data sheet to EPA.

In the 1988 audit, 55 percent of the 137 laboratories that received the audit package returned data. Table 7 shows the categories of participants, the number of participants who requested participation in the Method 5 audit, and the number who actually returned data. A total of 170 meter boxes were audited.

TABLE 7. METHOD 5 AUDIT PARTICIPANTS

Category	No. receiving orifice	No. returning data
Contractors	68	37
Industry	46	26
Foreign	5	4
Federal	2	2
State	12	5
Local	4	2
Total	137	76

Figure 1 is a cumulative histogram that shows the percent accuracy obtained by participants in the Method 5 audit, expressed as the percent difference from the expected (EPA) value. The Code of Federal Regulations[1] requires that the dry gas meter be calibrated within an accuracy of 2 percent. Figure 1 shows that 57 percent of the reporting laboratories attained this accuracy. This is approximately the same as in 1987.

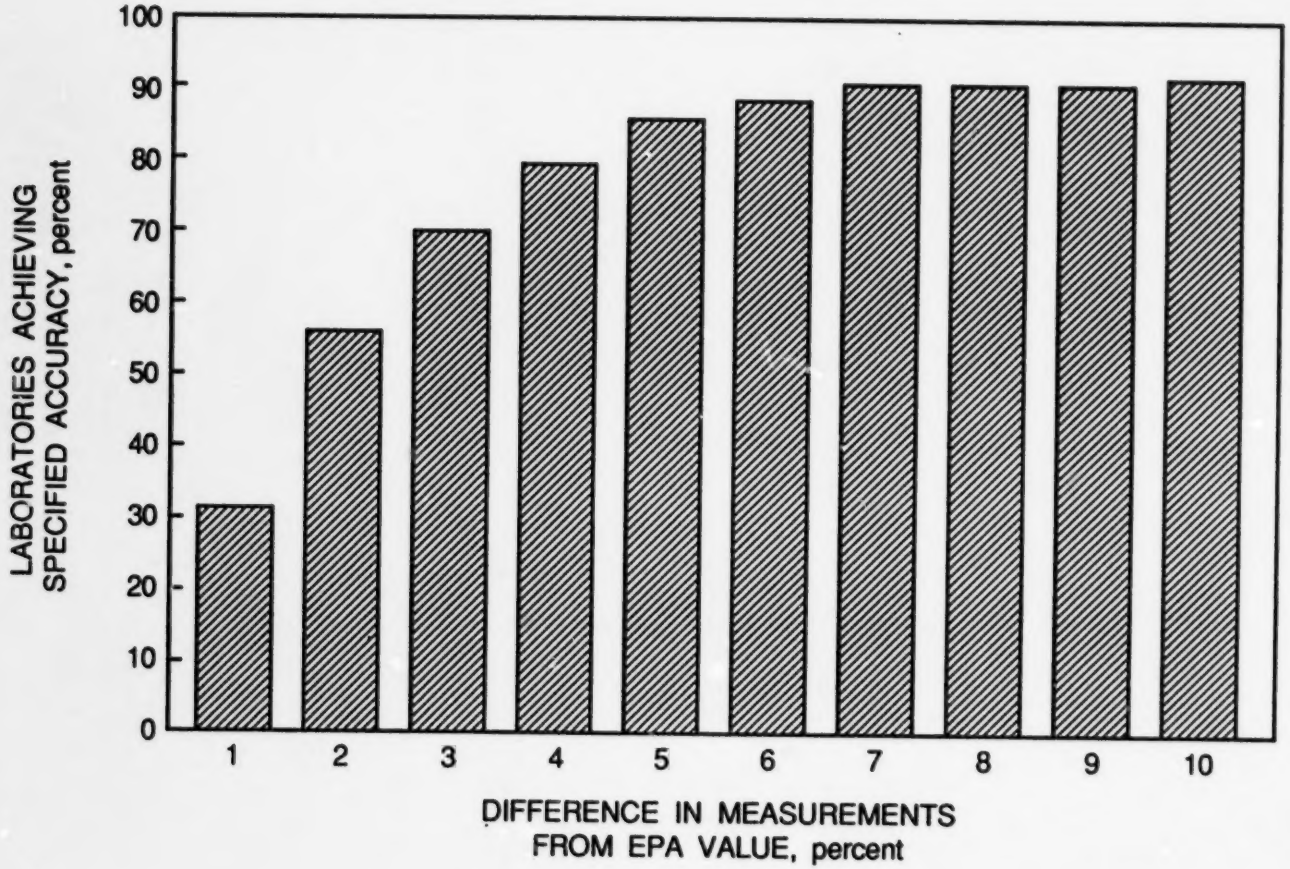

FIGURE 1. Cumulative accuracy for participants in method 5 audit.

SECTION 5

METHOD 6 AUDIT

The Method 6 audit checks the participants' abilities to quantitatively analyze Method 6 samples for sulfur dioxide content. The audit set consists of three aqueous dilutions of 10 N sulfuric acid in 25 mL sealed glass ampoules. The analyst withdraws 5 mL from each ampoule, adds 30 mL of 3 percent hydrogen peroxide, and dilutes this sample to 100 mL with distilled water. A 20-mL aliquot is then withdrawn from the diluted sample, 80 mL of 100 percent isopropanol and a few drops of thorin indicator are added, and the sample is titrated with barium perchlorate to a pink endpoint. In calculating the results, the participants assume an original liquid sample volume of 100 mL and a gas sample volume of 0.021 dry standard cubic meter (DSCM) of stack gas.

Table 8 shows the categories of the participants and compares the total number of participants requesting participation with the number returning data. In the 1988 audit, 62 percent of the 121 laboratories that received the audit package returned data.

TABLE 8. METHOD 6 AUDIT PARTICIPANTS

Category	No. receiving samples	No. returning data
Contractors	61	37
Industry	40	24
Foreign	4	2
Federal	1	0
State	10	8
Local	5	4
Total	121	75

Table 9 shows the percentage of laboratories that achieved 5 and 10 percent accuracy for each of the three different concentrations in the Method 6 audit. At least 72 percent of the reporting laboratories achieved an accuracy within 5 percent for all three concentrations. This is the accuracy criterion used for acceptable source SO_2 compliance audit results (Section 4.4 of Method 6).

TABLE 9. SUMMARY OF SOURCE SO_2 AUDITS

Concentration (mg/DSCM)	% Laboratories accurate within 5%	% Laboratories accurate within 10%
305.0	73.3	88.0
610.0	72.0	90.7
1296.0	88.0	93.3
N	75	

SECTION 6

METHOD 7 AUDIT

The Method 7 audit checks the participants' ability to quantitatively analyze Method 7 samples for nitrate content. The NO_x audit set consists of three aqueous dilutions of a potassium nitrate solution in glass ampoules that are autoclaved after sealing so that bacteria that might attack the nitrate are destroyed. The analyst withdraws 5 mL of solution from an ampoule, adds this with 25 mL of Method 7 absorbing solution to a flask, adjusts the pH with sodium hydroxide, and dilutes to 50 mL with distilled water. A 25-mL aliquot is withdrawn from the diluted sample, placed in an evaporating dish, and analyzed as described in Section 4.3 of Method 7.[1] After this treatment is completed, the absorbance is measured at 410 nanometers (nm) with a calibrated spectrophotometer. In calculating the concentrations, the participant assumes that 2000 mL of stack gas was sampled.

Table 10 shows the total number of laboratories requesting participation and the number that returned data for the 1988 Method 7 audit. Sixty-six percent of the 91 laboratories receiving the audit package returned data.

TABLE 10. METHOD 7 AUDIT PARTICIPANTS

Category	No. receiving samples	No. returning data
Contractors	50	30
Industry	27	18
Foreign	3	2
Federal	1	1
State	5	4
Local	5	5
Total	91	60

The percentage of laboratories that achieved 5 and 10 percent accuracy for each of the three concentrations is shown in Table 11. Seventy-two percent of the reporting laboratories achieved an accuracy within 10 percent on all concentrations. Ten percent is the minimum level of accuracy for acceptable NO_x compliance audit samples (Section 4.4 of Method 7).

TABLE 11. SUMMARY OF SOURCE NO_x AUDIT

Concentration (mg/DSCM)	% Laboratories accurate within 5%	% Laboratories accurate within 10%
125.0	60.0	71.7
284.0	69.5	79.7
637.0	55.0	71.7
N	60	

SECTION 7

METHOD 19 AUDIT

Standards of performance for newer electric utility steam generators (Subpart Da of 40 CFR 60) allow coal sampling and analysis to serve as an acceptable method for determining sulfur concentration in the scrubber inlet flue gas. The coal audit checks participants' ability to analyze coal samples for sulfur, ash, moisture, and Btu content.

The coal audit samples consisted of two samples each with 50 grams (g) of 60-mesh coal but with different parameter levels. The following American Society for Testing and Materials (ASTM) procedures [6] were recommended, but not required, for participants' use in analyzing the coal samples:

- ASTM D-3177 (Standard Test Method for Total Sulfur in the Analysis of Coal and Coke)
- ASTM D-3174 (Standard Test Method for Ash in the Analysis Sample of Coal and Coke)
- ASTM D-3173 (Test for Moisture in the Analysis Sample of Coal)
- ASTM D-2015 (Standard Test Method for Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Method)

Participants measured the parameters and reported their results for moisture (%) on an as-received basis, and their results for sulfur (%), ash (%), and gross calorific value (Btu/lb) on a dry basis.

In both audits, 90 percent of the laboratories that received the audit package returned data. Table 12 shows the total number of laboratories requesting participation and the number that returned data for the two coal audits (0388 and 0988).

TABLE 12. COAL AUDIT PARTICIPANTS

Category	No. requesting samples		No. returning data	
	0388	0988	0388	0988
Contractors	52	47	40	42
Industry	45	41	42	39
Federal	0	0	0	0
State	10	10	10	10
Local	4	4	4	4
Total	111	102	96	95

Tables 13 and 14 summarize the coal audit results. The number of analyses is greater than the number of participants because some companies had more than one laboratory participating. Each laboratory received its own set of samples and was asked to analyze the samples in duplicate. Accuracies of 5 and 10 percent were chosen as the target criteria for each of the four parameters.

Comparison of the 0388 audit to the 0988 audit shows that the results of both concentrations of the sulfur were better in the 0388 audit. The moisture results were the same in both audits.

TABLE 13. SOURCE COAL AUDIT--0388

Expected value	No. of analyses*	Laboratories accurate within 5% (%)	Laboratories accurate within 10% (%)
		Sulfur	
0.77	(1) 125	73.6	90.4
	(2) 120	67.5	90.8
2.05	(1) 125	82.4	95.2
	(2) 120	82.5	94.2
		Moisture	
0.94	(1) 125	31.2	56.8
	(2) 119	24.4	56.3
3.54	(1) 125	48.8	83.2
	(2) 119	52.9	83.2
		Ash	
7.92	(1) 125	94.4	97.6
	(2) 120	95.0	97.5
13.28	(1) 125	96.8	99.2
	(2) 120	98.3	100.0
		Gross Calorific	
13309	(1) 121	99.2	100.0
	(2) 117	99.1	99.1
13333	(1) 121	99.2	100.0
	(2) 117	99.1	100.0

*Numbers in parentheses indicate first and second analyses.

TABLE 14. SOURCE COAL AUDIT--0988

Expected value	No. of analyses*	Laboratories accurate within 5% (%)	Laboratories accurate within 10% (%)
		Sulfur	
4.08	(1) 114	71.1	88.6
	(2) 111	71.2	85.6
4.59	(1) 112	73.2	91.1
	(2) 109	70.6	90.8
		Moisture	
1.99	(1) 113	30.1	61.9
	(2) 110	30.0	61.8
7.59	(1) 115	47.8	88.7
	(2) 112	51.8	90.2
		Ash	
14.75	(1) 115	69.6	97.4
	(2) 112	70.5	97.3
17.84	(1) 113	98.2	100.0
	(2) 110	99.1	100.0
		Gross Calorific	
11761	(1) 109	92.7	100.0
	(2) 106	95.3	100.0
11823	(1) 107	98.1	99.1
	(2) 104	99.0	99.0

*Numbers in parentheses indicate first and second analyses.

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APPENDIX

FREQUENCY DISTRIBUTIONS

The following frequency distributions are provided to allow each participating laboratory to compare its performance to the performance of other laboratories that participated in the audit. For example, Table A-1 (Orsat) shows that for CO_2, 50 percent of the participants reported results within 4.94 percent of the true value. Similarly for O_2, 50 percent of the participants reported results within 1.12 percent of the true value.

TABLE A-1. NATIONAL ORSAT AUDIT FREQUENCY DISTRIBUTION OF ABSOLUTE PERCENT DIFFERENCES OF EXPECTED AND REPORTED VALUES

Sample no.	No.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.
							CO_2							
8000	109	0.00	1.23	2.47	3.70	3.70	4.94	6.17	7.41	8.64	12.35	65.43	7.11	8.94
							O_2							
8000	109	0.00	1.12	1.12	1.12	1.12	1.12	2.25	3.37	4.49	6.74	12.36	2.72	2.72
							CO							
8000	67	0.00	0.00	0.00	5.00	25.00	25.00	37.50	37.50	50.00	52.50	75.00	26.31	22.42

TABLE A-2. DGM FREQUENCY DISTRIBUTION OF ABSOLUTE PERCENT DIFFERENCE

Sample no.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.	Skewness	Median
510	0.0	0.3	0.6	1.0	1.3	1.8	2.3	3.0	4.1	6.7	21.0	3.1	3.9	2.34	1.8
462	0.0	0.3	0.6	0.9	1.3	1.6	1.9	2.5	3.3	4.3	6.8	2.0	1.6	0.99	1.6

TABLE A-3. SO_2 FREQUENCY DISTRIBUTION OF PERCENT DIFFERENCE--NO OUTLIERS REMOVED

Sample no.	No.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.
4	75	0.05	0.92	1.88	2.50	3.08	3.49	3.77	4.92	6.46	10.12	390.51	10.83	45.88
6	75	0.01	0.35	0.64	0.85	1.23	1.60	2.09	2.65	3.40	7.40	402.65	9.35	47.47
8	75	0.03	0.68	1.08	1.51	2.03	2.62	3.24	4.18	7.24	12.46	399.61	10.82	47.04

TABLE A-4. NO_x FREQUENCY DISTRIBUTION OF PERCENT DIFFERENCE--NO OUTLIERS REMOVED

Sample no.	No.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.
1	60	0.16	0.63	0.94	1.65	2.20	4.47	5.16	9.38	21.40	45.04	1022.76	31.04	133.37
3	60	0.00	0.80	1.06	1.54	2.82	3.44	5.31	8.53	13.58	71.31	1039.20	39.08	143.68
5	59	0.04	0.46	1.06	1.76	2.82	3.17	3.45	5.49	11.94	35.21	878.52	26.72	116.68

TABLE A-5. NATIONAL COAL AUDIT FREQUENCY DISTRIBUTION OF ABSOLUTE PERCENT DIFFERENCES OF EXPECTED AND REPORTED VALUES - STUDY 0388

Sample no.	No.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.
							Sulfur							
2000	245	0.00	0.49	0.49	1.46	1.95	1.95	2.44	3.51	4.88	7.32	25.37	3.23	3.67
8000	245	0.00	0.00	1.30	1.30	2.60	2.60	3.90	3.90	6.49	9.09	240.26	6.72	22.66
							Moisture							
2000	244	0.00	2.13	3.19	5.32	6.38	8.51	10.64	13.83	17.02	29.26	276.60	15.44	28.32
8000	244	0.00	0.99	1.98	2.68	3.95	4.80	5.93	7.91	9.60	14.27	53.11	7.15	8.63
							Ash							
2000	245	0.00	0.15	0.23	0.38	0.45	0.68	0.83	1.07	1.51	1.99	12.80	0.99	1.31
8000	245	0.00	0.25	0.38	0.51	0.76	1.01	1.39	1.64	2.15	3.71	141.79	2.65	11.84
							Gross Calorific							
2000	238	0.00	0.04	0.07	0.11	0.16	0.23	0.30	0.38	0.48	0.76	12.71	0.41	0.97
8000	238	0.00	0.06	0.10	0.15	0.22	0.31	0.38	0.50	0.68	1.22	8.03	0.62	1.10

TABLE A-6. NATIONAL COAL AUDIT FREQUENCY DISTRIBUTION OF ABSOLUTE PERCENT DIFFERENCES OF EXPECTED AND REPORTED VALUES - STUDY 0988

Sample no.	No.	Min.	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max.	Mean	Std. dev.
							Sulfur							
3000	221	0.00	0.65	1.31	1.74	2.40	3.05	3.92	4.66	6.10	9.50	44.44	4.69	6.18
7000	225	0.00	0.88	1.47	1.96	2.70	3.19	3.92	4.90	6.08	13.73	33.82	4.94	5.36
							Moisture							
3000	223	0.00	2.21	3.52	4.62	6.03	7.54	9.25	12.56	16.08	23.72	108.04	11.62	13.50
7000	227	0.00	0.79	1.79	2.56	3.72	5.01	5.67	6.53	7.51	10.41	28.99	5.28	4.25
							Ash							
3000	223	0.00	0.28	0.67	0.96	2.29	1.68	2.02	2.41	2.91	3.48	8.63	1.82	1.29
7000	227	0.00	0.60	1.53	2.47	3.19	3.59	4.14	4.99	5.72	6.60	13.36	3.78	2.41
							Gross Calorific							
3000	211	0.00	0.10	0.20	0.30	0.42	0.52	0.65	0.89	1.20	1.53	15.88	0.83	1.49
7000	215	0.00	0.09	0.19	0.30	0.37	0.48	0.63	0.80	1.06	2.49	7.94	1.03	1.65